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CLASSIFICATION OF RICE SOILS OF INDIA

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Rice requires high temperature and high humidity with abundant supply of water during its life period. Rainfall and its distribution, temperature and day-length have marked influence on the growth of the crop and the yield of grain. Its cultivation in tropical and subtropical zones is widespread. Most of the rice areas lie between the Equator and 40° N latitude and between 70° and 140° E longitude. India is the largest rice-growing country of the world and the crop is cultivated under varied conditions of soil and climate provided the requirement of water is adequately met. Rice occupies more than 30 percent of the total annual cultivated area of the country and its cultivation extends from 8° to 35°N latitude under widely varying conditions of rainfall and altitude. There are rice grown at sea level in the river deltas, in areas even below the sea level with protective embankments as in parts of Kerala, in 15 to 20 feet of water as the deep water paddy in the States of Assam and West Bengal and at altitudes of 3,000 to 5,000 feet or even more as in Kashmir and the slopes of Himalayas. The crop is semi-aquatic in nature and has a peculiar property of tolerating a wide range of soil reaction (pH varying from 4.0 to 9.0) but it is best grown within the pH limits of 5 to 7.

Soil is a product of diverse factors of which climate constitutes an important element. India has thus varied soils with varied climate. The different states of the country some of which are widely separated have differing soil and climatic conditions but rice is grown in almost all the states provided water supply is not limiting. Its cultivation is mostly concentrated in the river valleys, deltas and low-lying coastal areas of north eastern and southern India and in the states of Assam, Manipur, Tripura, Andaman and Nicobar Islands, West Bengal, Orissa, Bihar, Andhra Pradesh, Madras, Mysore, Kerala and Madhya Pradesh. Uttar Pradesh has considerable area under paddy in the eastern and northern parts. Paddy cultivation in the Punjab is also increasing with the increase in water-logged areas.

There are many varieties of paddy cultivated in the country which may broadly be divided into two groups, namely (1) wet land paddy and (2) dry land paddy according to their adaptability to soil conditions. The wet land paddy is grown on flooded soils or on soils with natural or artificially induced impermeable layers near below the surface. Dry land paddy is grown on permeable soils and the crop meets the requirement of nutrients and moisture by sending roots deep into the soils. Wet land paddy is the most widely cultivated crop of the country whereas dry land paddy is cultivated to a certain extent in the states of Bihar, Uttar Pradesh and Madhya Pradesh. In India there are three rice-growing seasons on the basis of which Ghose *et al* (1956) grouped the rice areas into five regions, viz; (1) North-Eastern Region, (2) Southern Region, (3) Central Region, (4) Western Region and (5) Northern Region.

Soil Condition for Rice Culture

Dry land paddy is adaptable to soi which is permeable irrespective of texture. For successful culture of wet land paddy, the most important property of the soil is its capability to hold water on the surface. Thus, the fine textured soils viz., silty clay loam, clay loam and clay with less of permeability are more suitable and higher yields of paddy are obtained. In India twenty-five broad soil classes have been differentiated of which excepting few, the rest grow rice. The success achieved, however, varies and depends on soil management, fertilizer practices and above all the

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availability of water during the growth period. In certain areas of the Punjab due to faulty irrigation a new situation has arisen during recent years as the water table has risen very high creating in some cases water-logged conditions. Extensive wheat fields have now been converted into good paddy lands. The most important groups of soils in which the crop is grown in the country are alluvial soils (including old and new alluvium, coastal and deltaic alluvium), red soils, laterite and lateritic soils, black soils, saline and alkali soils, *tarai* soils and peatly and marshy soils. Most of the country's paddy is grown on alluvial soils and red and laterite and lateritic soils.

Rice Growing Soils of the States

Assam

The important rice growing soils of the state are (1) alluvial soils of Brahmaputra and Surma valleys, (2) red soils under terraced conditions on hill sides and (3) laterite and lateritic soils. The soils of the Brahmaputra alluvium are partly new and partly old. The variation in mechanical composition is mainly a result of the varying composition of the river borne material deposited at different time and under different condition. The soils are acidic to neutral and are, on an average of sandy loam type. The recent alluvium has generally a high pH even greater than 7 and old alluvial soils have a low pH varying from 4.5 to 6.0. The soils of Surma valley are not much different from the above except that they are of finer texture. The valley is characterised by its swampy nature and abundance of *bheels*, the soils of which contain large percentage of organic matter. The red and laterite soils of Assam were studied by Raychaudhuri (1941). Considering the morphological features of the profile, the red soils were classed as red loams, characterised by argillaceous soil with a cloddy structure and the presence of only small amounts of concretionery material. Rice is grown in these soils of hilly region under terraced condition with irrigation from hill streams. The Assam soils are characterised by a fairly good nitrogen content the average being about 0.15 per cent. In heavy soils containing high percentages of nitrogen, the average yield of paddy is around 3,000 lbs. per acre and response to manures low. In poorer soils where the yield is below 1,600 lbs. per acre both nitrogen and phosphoric acid are recommended to push up yields.

West Bengal

The rice soils of the state include (1) laterite and lateritic soils, (2) red soils, (3) *tarai* soils and (4) alluvial soils. The laterite and lateritic lands are undulating and have many tiny rivulets. Soils are slightly to highly eroded and are red. At places honey-combed structure laterite beds are exposed. Surrounding these are terraced paddy fields extending down to the bed of rivulets. The paddy fields have an yellowish gray colour on the top and red below. The red soils have varying thickness with or without lime concretions in profile. Pisolitic concretions, containing sesquioxide at places increase in great numbers. The laterite and red soils often occur in close proximity to each other. The subsoil is either honey-combed laterite or *murum* or quartz having sesquioxides cementing them or ferromanganese concretions of pisolitic type. Over these subsoils rest red soils. This intimate association of the great soil groups is complex in many rice growing tracts of West Bengal. Alluvial soils of the state are most intensively cultivated and paddy forms the most important crop. These soils include coastal and deltaic alluvium and the alluvium of the major rivers namely the Ganges and the rivers originating from the Chotanagpur plateau. A type of clay pan develops in wet land paddy fields in the coastal area. A large accumulation of fine materials particularly clay, a high percentage of Al_2O_3, low contents of CaO and porespace, a compact consistency and a prismatic structure are the special features of the pan horizon. Gupta (1960) studied the effects of different fertilizers on paddy in relation to soil categories in the district of Birbhum. The results of his observations are given in table 1.

TABLE 1

Increase in the yield of paddy grains due to fertilizer treatment in different soil associations of West Bengal

Soils associations	Control lbs/acre	Percentage increase in yield due to different treatments					
		N over control	NP over control	NK over control	NPK over control	P over N	K over N
Laterite soils	1875	14.6	25.7	18.6	27.4	11.1	3.6
Lateritic soils (Gondwana soils)	1791	30.0	46.9	34.6	49.6	16.9	4.6
Red Soils	1806	23.8	42.4	30.6	43.8	18.6	6.3
Raimahal Flatland soils	1854	25.4	38.5	11.5	36.8	3.1	nil

Note: N = N 25 lbs/acre
P = P_2O_5 ,,
K = K_2O ,,

Bihar

The rice soils of Bihar include alluvium to the north and the south of the Ganges and the hilly soils of Chotanagpur. Mukherjee (1952) described the soils of Bihar in relation to their manurial requirements. The alluvial soils north of the Ganges vary from clay loams to sandy loams and are neutral to somewhat alkaline. Two distinct zones of alluvial soils, non-calcareous and calcareous, are met with. Raychaudhuri and Banerjee (1954) studied a profile of calcareous soil from *Pusa growing paddy* and found it to resemble the paddy soil of North China in respect of physical and chemical properties. The alluvial soils south of the Ganges are heavier and finer in texture than those of the northern part. Rice crop is mainly concentrated south of the Ganges and the area is well-supplied with irrigation facilities. Rice is the main crop in the hilly areas of Chotanagpur where terraced cultivation under rainfed condition is practised. The soils are red loams throughout Chotanagpur and are acidic, pH varying from 5.0 to 6.8.

Uttrar Pradesh

Rice cultivation in this state is confined to (1) the mountainous region in the north, (2) sub-montane tract below the Himalayas known as *tarai* and (3) the fertile Gangetic alluvium in the central and eastern parts. In the mountainous region the soils are generally shallow with underlying rocks, porous and gravelly. This region receives very heavy rains annually approaching 80" and grows best quality table rice under terraced condition. The submontane tract popularly known as *tarai* starts as belt below the Himalayas from the district of Dehra Dun to that of Deoria and is characterised by excessive soil moisture. These soils grow good rice crops. Agarwal et al (1955) classified the soils of Nainital *tarai* and placed them into five textural-cum-calci-morphic soil associations, namely, (1) Matkota clay loam, (2) Matkota loam—highly calcareous, (3) Matkota loam—non-calcareous and (4) Matkota sandy loam and super-imposed the results of cropping experiments on them. They found Matkota clay loam to be best suited for paddy crop. The alluvial soils of eastern and north-eastern Uttar Pradesh are well suited for paddy cultivation. Here a heavy type of soil, alluvial in origin, known as *dhankar* in local agricultural parlance is exclusively used for paddy cultivation. It is a typical soil formation in the Gangetic alluvium of Uttar Pradesh extending to Shahabad district of Bihar which arises when free drainage is impeded and hydrologic elements work in place of the normal processes of soil formation in the zonal pedogenic complex of the tract. Topographically, these soils occur in flat-basin shaped depressions and low-lying tracts located far away from any significant drainage channel. These soils are characterised by a horizon of *Kankar* formation at shallow depth in the profile and eluviation is confined to this depth only. These soils have been classified according to international system of soil classification as the sub-tropical vlei or gray hydromorphic soil of the intrazonal order. These soils of alluvial origin provide interesting study as they are particularly suited to paddy. Morphological features and physical and chemical characteristics of a typical profile is given in table 2.

TABLE 2

Morphological features and physical and chemical characteristics of a typical **Dhankar** *profile of Uttar Pradesh (Gupta, Agarwal and Mehrotra, 1957)*

Horison	Depth in inches.	Morphological descriptions	C. Sand	F. Sand	Silt	Clay	pH	$CaCO_3$ per-cent	Total N per-cent	Organic Carbon percent	C/N	Cation exchange capacity m.e.%	SiO_2/R_2O_3
Acn	0-6	Light brownish gray (2.5y6/2 dry) to grayish brown (2.5 Y 5/2, moist) mottled with red and yellow clay loam; very stiff when dry, compact moderately strong medium sub-angular blocky structure; neutral in reaction; organic matter and roots of paddy embedded with rusty iron stains and some dark brown nodular concretions present.	0.7	48.2	23.1	29.1	6.6	0.8	0.07	0.567	8.1	52.0	2.46
Bgen	6-30	Light olive (5 Y 6/3, dry) to olive gray (5 Y 5/2 moist) clay loam, heavier than above with plenty of coarse yellow mottlings; sticky when wet, very hard and compact; strongly blocky neutral to slightly alkaline; the dark brown nodules of iron have increased in number and size but no lime concretions.	1.0	31.8	32.8	36.0	6.9	0.9	0.042	0.257	6.1	43.3	2.31
CCa	30-42	Light gray (5 Y 7/2, dry) to light olive gray or pale olive gray (5 Y 6/2-6/3, moist) gritty loam in a sharply defined thick *Kankar* pan; hard and compact; very massive; moderate to strongly alkaline; *Kankar* stained yellow in the upper layer and heavy loam replaced by pockets of lighter soil in the lower layer, *Kankar* of large size and irregular shape; iron nodules absent.	0.1	21.3	30.3	23.9	8.3	21.9	0.044	0.317	7.3	47.9	2.45
	42-54		0.1	46.3	27.9	16.3	8.5	9.4	0.014	0.170	12.0	40.8	2.50
C_2	54-72	Light gray (10 YR 7/2, dry) to light brownish gray (10 YR 6/2 moist), sandy soil, loose, single grained; strongly alkaline; moderately calcareous but possessing little lime concretions; no iron nodules.	0.1	77.9	10.2	7.5	8.5	5.9	0.008	0.090	11.1	45.0	2.45

Punjab

Rice is a minor crop of the state, but its cultivation is gaining ground day by day due to rise in water-table and water-logged conditions in certain areas. The crop is grown in the hilly areas under high rainfall and terraced condition and in the irrigated plains served by inundation canals. The intra-zonal saline and alkali soils of the state are also under paddy cutivation. Sharma (1955) classified the soils into recognized world groups according to climatic conditions as : Hilly zone, per humid-Pedalfer black coloured soils of podsol; Foothill zone, humid-transitional soils of alluvial origin; Indo-Gangetic alluvial plains, semi-humid—Pedocal Chestnut coloured soils of alluvial origin. The terraced soils of hill slopes are acidic and richer in humus and nitrogen but deficient in phosphoric acid. The other soils of alluvial origin including the transitional soils are neutral to alkaline and deficient in organic matter and nitrogen. Rice generally responds to the application of nitrogen.

Madhya Pradesh

The bulk of the area under rice crop in the state is contributed by the South Eastern districts known as the Chhatisgarh plains. Most of area belong to the Mahanadi basin. For revenue purpose, the soils have been grouped into four classes, namely *matasi*, *dorsa*, *kankar* and *bhata*. *Matasi* and *dorsa* are well suited for paddy cultivation. *Matasi* soil occurs in upland or level land and are red to yellow in colour, sandy loam to clay loam in texture. *Dorsa* soils occur in slopes and are darker in colour, texturally slightly heavier than the above and have properties intermediate between *matasi* and *kankar*. A study of electrochemical properties of hydrogen clays of a yellow soil from Labhandi, Madhya Pradesh, locally known as *matasi* revealed a low silica/sesquioxide and silica/alumina ratio varying respectively between 1.7 and 1.9 and between 1.8 and 2.0 characteristic of dominent kaolinitic make-up throughout the depth of the profile (Roy and Das, 1953). These soils are lateritic in nature. The rice growing soils of Chhatisgarh Division were classified into three types based on clay content, namely, (1) light soils containing less than 25% clay, (2) loams containing 25-45% clay and (3) clays containing more than 45% clay. All the soils are deficient in phosphate. The pH varies from 5.4 to 8.4,C/N ratio has a wide range of 3.4 to 32.2. The humus content is low. The texture of the soils is found to influence the quality and yield of rice. The soils respond well to application of nitrogen and phosphate. In other areas of the state rice is grown under irrigation in medium textured soils such as the *domatta* and *sehra* soils of the Jabalpur district.

Orissa

Paddy is the main crop of the state and occupies about 70% of the total cultivated area. There are three methods of cultivation viz. (1) dry, (2) semi-dry and (3) wet or swamp cultivation according to the situation of the land and water availability Dry cultivation is practised in the northern plateau, central table land and eastern ghats, the hill slopes entirely under rainfed condition. The high lands of the coastal tracts which cannot be irrigated with canal or river water are also similarly cultivated. Semi-dry cultivation is practised in the delta tracts and in the *berna* (lower slopes under terraced condition) and *bahal* (low-lying) lands of the hilly tracts. In the northern plateau and eastern ghat regions transplanting is customary while in the central table land and coastal tracts rice is sown broadcast to overcome the danger of excess rain and flood water. The state has been divided into four divisions, namely (1) northern plateau, (2) central table land, (3) eastern ghats and (4) coastal region and all these regions fall under sub-humid to humid climatic conditions. Good crops of paddy are raised in all the regions. The soils of the northern plateau have been classified as red earth. The soils are neutral in reaction, poor in organic matter and plant nutrients and are loamy to sandy loam

in texture. Two distinct intra-zonal soil types viz. Planosol and Rendzina are also met with in this plateau. The central table land has three distinct soil types, namely, (1) North eastern section with yellow earth, (2) Central and south-west section of black earth and (3) Eastern plain of laterites. The soils are neutral in reaction loamy in texture and at places full of ferruginous concretions. They are deeply leached of bases. The coastal region has alluvial or fluviogenic soil. The textural characteristics vary from north of south. The soils of the northern section are sandy to sandy loam; of the central section clay loam to stiff clay. Mahanadi delta soils are stratified into clay, silt, sand and grit.

The following table will show the performance of the different soil groups with respect to paddy yield in the State of Orissa (Sahu, 1951).

Tract	District	Soil Group	Textural Class	Yield in lbs. per acre
Northern Plateau	Mayurbhanj	Red Earth	Clay loam	1,800
	Sundergarh	,,	,,	1,700
	Keonjhar	,,	,,	1,600
Central Table land	Sambalpur	Old alluvium	,,	1,900
	Bolangir Patna	,,	,,	1,900
	Dhenkanal (Angul)	Regur	Clayey	1,800
Eastern Ghat Region	Koraput	Laterite	Clay loam	1,600
Coastal Region	Cuttack	Alluvium	Clayey	2,200
	Puri	,,	Sandy loam	1,890
	Balasore	,,	Clay loam	2,000
	Ganjam	,,	Loam	2,100

All the above soils respond well to nitrogenous and phosphatic fertilizers.

Andhra Pradesh

The main soil groups in the state are alluvial soils, red soils, laterites and black soils or regur. The main rice-growing tracts are the deltaic areas of the Krishna and the Godavari. The soils in the deltaic areas and also along the coast line are alluvial and are known as deltaic alluvium and coastal alluvium. The composition of the soils and of the strata varies with the nature of silt brought down by the rivers from the catchment areas. The other important rice soils are the red and laterite soils of state. The black soils or regur is put under rice cultivation mainly under major irrigation projects having water of good quality. The black soils are heavy in texture, have a good supply of lime and pH of about 8.5. They are poor in nitrogen and phosphoric acid but well supplied with potash. The red soils vary in texture from sandy to loamy, with a low soluble salt content and are usually poor in plant nutrients.

Madras

Paddy is the most important crop of the state and is grown in four district regions, namely, (1) the Malabar coast, a region of heavy rainfall of over 100" comprising undulating land with low hills and valleys, (2) central and southern districts, a zone of low rainfall not exceeding 30 inches, (3) the alluvial soil region along

the banks of the Cauvery and deltaic areas and (4) the east coast district with a rainfall of over 40inches. The rice growing soils of the four regions may broadly be classified into red soil, laterite or lateritic soil, black soil, mixed red and black soil and alluvial soil. Rice is grown in the Malabar coast on terraced fields and also in valleys. The soils are laterite or red ferruginous and are poor in bases. In the region of low rainfall the soils are red, black and mixed red and black depending on topographical situation. The nutrient content is medium to low. The alluvial soils include deltaic alluvium and coastal alluvium. The coastal alluvium are sandy and have low fertility. The deltaic alluvium are on the other hand heavier and richer in plant nutrients. The profile study reveals alternate layers of sand and silt as they are deposited by the rivers. The soils are poor in organic matter, nitrogen and P_2O_5 but rich in potash and lime. The cation exchange capacity is quite high and the pH varies between 7 and 8.2. Raychaudhuri and Banerjee (1954) studied a typical soil profile from Coimbatore growing rice for the last 200 years in the same field. The soil is heavier at the top becoming light towards the bottom. In physical and chemical characteristics, the soil was found to resemble the " swamp " type of rice soils of Siam.

Mysore

The main soil groups in the state are (1) the coastal alluvium, (2) the laterite soil, (3) the red soil, (4) black soil and (5) the mixed red and black soil. According to either the occurrence of heavy rainfall or the availability of irrigation, paddy is grown to a larger or smaller extent in all the above soil groups. However, paddy is more extensively grown in red soils, red loams and laterite soils. The soils loam to clay loam in texture from amongst the above groups are more suited for paddy cultivation. The laterite soils are acidic (pH ranging between 5.0 and 6.0) and low in bases due to excessive leaching. These soils are poor in plant nutrients but rich in organic matter. The red soils are neutral in reaction and low in soluble salt content. They are poor in organic matter, nitrogen and phosphoric acid but well supplied with potash.

Kerala

Situated in the humid tropical belt, the whole of the state is characterised by high rainfall and humidity. The main soil groups well suited for paddy cultivation are (1) alluvial soil, (2) peaty or *Kari* soil (3) red soil and (4) laterite and lateritic soils. The coastal alluvium are sandy having a low water holding capacity and low nutrient status whereas the alluvium on the banks of the main rivers are fertile and intensively cultivated with paddy. The peaty or *Kari* soils are generally submerged under water during monsoon. As soon as rain ceases they are put under paddy cultivation. The lands are black, heavy and highly acidic pH sometimes being as low as 3.9. They contain 10-40 per cent of organic matter. Raychaudhuri and Anantharaman (1960) studied the acid peaty or *Kari* soil growing paddy and confirmed that the infertility of *Kari* soil is due mainly to soluble salts and organic acids rather than to lack of nutrients. These soils have montmorillonite and illite type of clays. The low level laterites grow paddy to a considerable extent in the state. The laterite soils are poor in N, P, K and organic matter and pH ranges between 4.5 to 6.0. Morphological description of a typical laterite profile is given below.

Depth feet	Morphological features
0 - 1	Yellowish brown (10 Y R 5/6), clay loam soil, with pebbles about 2 cm size, few grass root.
1 - 6	Hard laterite layer, top portion being crumbly and breaks into irregular shaped pieces; cellular and porous below; colours varying red, reddish brown and yellow, irregularly mottled; quartz grains and irregular small bits seen embedded in iron matrix; no roots.

Maharashtra and Gujrat

The rice soils of these two states fall into four categories, namely, (1) alluvial soils in the north and south Gujarat tracts, Broach and Surat, (2) the coastal salt lands of the west, (3) the medium black soils of the Deccan Plateau, (4) the laterite and lateritic soils of Ratnagiri. All the above soils respond well to nitrogenous and phosphatic fertilizers.

Classification

In the foregoing pages an attempt has been made to show the nature and characteristics of the different soil classes extensively utilized for growing paddy throughout the country. Some of these are normally or fully developed soils or mature soils while others are immature. They thus fall in the three orders, namely zonal, intra-zonal and azonal according to the development under the influence of active factors respectively of soil genesis-climate and vegetation; or under the influence of some local factors of relief or parent material; or where none of the soil forming factors had sufficient time to act on them for development of definite soil characteristics. According to international system, the rice growing soils of India may thus be classified as follows:

Order	Sub-order	Great soils group	Remarks
Zonal	Dark coloured soils (semi -arid and sub-humid)	Black soil or *regur*	These soils are utilized for paddy cultivation in the states of Andhra Pradesh, Mysore Madras, Madhya Pradesh and Maharashtra under irrigated conditions.
	Light coloured podsolised soil of the timbered region (humid representing vertical zonality)	podsolic soil	Paddy is grow in the hill slopes of Himalayas in the north of Punjab and Uttar Pradesh under terraced condition.
	Lateritic soils of tropical and sub-tropical region	Red soil including red loam, red and yellow earths; laterite soils; latosol	These soils are extensively cultivated with paddy in the states of Assam, West Bengal, Bihar, Orissa, MadhyaPradesh, Andhra Pradesh, Madras, Mysore, Kerala and Maharashtra.
Intra-zonal	Halomorphic	Solonchak or saline soil; solonetz soils	Paddy is grown in these soils in the states of Punjab, Uttar Pradesh and other states of semi-arid and sub-humid region after amelioration of excess of salinity and alkali.
	Hydromorphic soils or marshes, swamps, seep areas and flats	Sub-tropical vlei	A typical example is *Dhankar* soil of Uttar Pradesh exclusively used for paddy cultivation.
		Planosol	Wet land paddy fields in coastal areas in West Bengal with a type of clay pan developed in them.

Order	Sub-order	Great soils group	Remarks
		Bog and half-bog soils	Typical examples are the peaty or *Kari* soils of Kerala, swampy soils of Madras and Assam, marshy soils of Bihar, West Bengal, Andhra Pradesh mainly used for paddy.
		Low-humic gley soils	A typical example is the *tarai* soil at the foot of the Himalayas.
Asonal Soil		Alluvial soils including the river alluvium deltaic alluvium and coastal alluvium	These are the most extensive rice growing soils of India. The most important river alluvium is represented by the Brahmaputra alluvium and Indo-Gangetic alluvium occurring in the northern and north-eastern states of the country. The deltaic alluvium and coastal alluvium occur in the states of West Bengal, Orissa, Andhra Pradesh, Madras, Kerala, and Maharashtra and grow very good crops of paddy.

Summary

Rice is the most important and extensively grown crop in India. The soil and climatic conditions under which the crops are grown are widely varied. The rice-growing soils have been discussed in details in respect of each state. According to the international system of soil classification the soils fall into three orders viz: zonal, intra-zonal and azonal and the great soil groups are represented by black soil or *regur*, podsolic soil, red soil including red loam, red and yellow earths, laterite soil, latosol; saline and alkari soil, sub-tropical vlei, planosol, bog and half bog soils and alluvial soil.

Reference

1. Agarwal, R.R., Mehrotra, C.L. and Gupta, C.P. (1955)
   Soil classification and soil mapping in Nainital Tarai *Proc. Natl. Acad. Sci.* (India) **24:** 46-59.
2. Ghose, R.L.M., Ghatge, M.B. and Subrahmanyan V. (1956)
   Rice in India, Indian Council of Agricultural Research, New Delhi, India.
3. Gupta, S.P. (1960),
   Soil category and fertilization of paddy (Birbhum) *Indian Jour. Agron.* **4** (No. 4) 238-245.
4. Gupta, R.N., Agarwal, R.R. and Mehrotra, C.L. (1957)
   Genesis and Pedo-chemical characteristics of *Dhankar:* Gray Hydromorphic soils in the lower Gangetic Plains of Uttar Pradesh. *Jour. Indian Soc. Soil Sci.* **5:** 5-12.

5. Mukherjee H.N. (1952)
Soils of Bihar and a new method of determining their manurial requirements. *Proc. Bihar Acad. Agri. Sci.* **1** (No. 1): 58-94.

6. Raychaudhuri, S.P. (1941)
Indian Jour. Agri. Sci. **11:** 220

7. Raychaudhuri, S.P. and Banerjee, B.S. (1954)
Studies on some profiles of soils growing paddy. *Jour. Indian Soc. Soil Sci.* **2:** 5-14.

8. Raychaudhuri, S.P. and Anantharaman, P.V. (1960)
Characteristic of some Indian acid soils growing paddy. *Jour. Indian Soc. Soil Sci.* **8:** 224-228.

9. Roy, B.B. and Das, S.C. (1953)
Electro-chemical properties of hydrogen clays from several Indian soils in relation to their mineralogical make-up.
Soil Sci. **76:** 97-105.

10. Sahu, B.N. (1951)
Land utilisation in Orissa, Orissa Govt. Press Cuttack.

11. Sharma, B.K. (1955)
M. Sc. Thesis, Punjab University.

SOME ASPECTS OF RICE BLAST AND VARIETAL RESISTANCE IN THAILAND

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Rice Blast in Thailand

The problem of rice blast disease was not considered serious in Thailand 8 or 9 years ago. However, during the past 5 or 6 years, outbreaks of the disease and extent of damage have been increasing rapidly. Some people believe the disease was introduced from Japan during World War II, while others, considering the worldwide distribution of the disease and the long history of rice culture in Thailand, think that it has been present but not recognized for many years. The spread of the disease during the past 5 or 6 years may be due to the change of rice varieties. In the past 5 or 6 years, new improved varieties produced through pure line selection have been recommended by the Government and the acreage planted to them has been increasing every year. Recently it was found that many of the new varieties are very susceptible to blast. In the Central Region, the most important rice producing area of Thailand, 4 out of 6 of the recommended varieties are very susceptible. As blast was not at all important in the past, no special effort was made to find varietal resistance in the early selection program.

In some of the countries in South-East Asia, blast is not yet a problem and in their rice breeding programs no special attention has been paid to blast. From the experience gained in Thailand it would seem to be well worthwhile for them to test for blast resistance in the early stages of their rice breeding program. This need may be further emphasized by the fact that many of the South-East Asian countries are increasing the use of fertilizers for higher rice production and this is well known to increase the possibilities for serious outbreaks of blast.

Seasonal Development of Blast and the Role of Micro-climate

Under varying climatic conditions blast manifests its symptoms on different parts of the rice plant at different stages of growth. In Thailand the disease develops as seedling blast in the nursery and as neck-rot on node-rot after emergence of the panicle. Little or no blast develops on the rice plant in the period between transplanting and heading.

From June 1959 to May 1960 field experiments were carried out every month, and seedling blast developed throughout the period by natural infection. Temperature, it appears, may not be a limiting factor for blast development in the field.

Rainfall does not seem to affect blast development directly as even though the rainfall is heavy during September and early October when rice has already been planted, there is very little leaf blast, while during the early months when rainfall is relatively low the nurseries are affected. The development is therefore determined mainly if not entirely, by the humid microclimate surrounding the seedlings in the nursery.

In the seedbed the seedlings grow close together and high humidity is retained among them from the commonly occurring late afternoon monsoon showers until the following morning. This enables the blast to develop. After transplanting, the seedlings are more widely separated and high humidity cannot be retained around the plants. The monsoon rain passes away quickly, usually in one or two hours, and the weather is fine during the rest of the day.

1 Former FAO Agricultural Officer

One experiment conducted in 1960 seemed to demonstrate very well the influence of the humidity of the micro-climate on the development of blast. Seeds of a very susceptible variety were sown in a plot which had been treated with a heavy application of nitrogenous fertilizer. After a month, seedlings in the center of the plot were killed completely by blast while the seedlings around the edge of the plot remained green and showed only a few blast lesions. These lesions were most numerous on the side of the plot away from the prevailing wind. This phenomenon has also been observed in many ordinary seedbeds.

From experiments and observations on the important role of the micro-humidity in the development of blast on seedlings, experiments were conducted in 1959 and 1960 to discover the optimum width of seedbed for reducing the micro-humidity around the seedlings and consequently for minimizing the blast damage. It was found that seedbeds consisting of narrow strips not more than half a meter in width suffer little damage from blast under normal climatic conditions. This narrow type of seedbed together with a suitable rate of seeding and the selection of an airy, not too humid site for the seedbed are recommended for reducing the damage caused by seedling blast. Field demonstrations based on these recommendations were made in 1960 and 1961 with good results.

Even though the air humidity may be relatively low during the days in November when most of the rice varieties are heading, heavy dews usually develop following the night drop in temperature producing a suitable micro-climate for the development of outbreaks of the neck-rot stage of blast which frequently occur at this time of year.

Methods for Testing Blast Resistance and Scoring Disease Reaction

Leaf blast and neck-rot are usually the two most destructive phases of blast disease. Tests for blast resistance may be conducted during either of these two stages. Testing at the neck-rot stage requires a long time and much space and incidence of the disease depends on natural weather conditions as it is not usually possible to control environmental conditions over a large area. Testing for leaf blast in the seedling stage is more convenient, requires less time and space and this method was therefore employed in the work carried out in Thailand. Tests of neck-rot resistance may be used to confirm the results obtained in seedling tests.

It is well known that humidity and soil fertility, particularly as regards nitrogen, are the two most important factors affecting the development of blast disease in the field. As rice varieties vary greatly in their reaction to blast, conditions in varietal susceptibility tests should be such that a susceptible variety is completely killed while more resistant varieties show varying degrees of damage. The methods used in Thailand are described and discussed below:

1) Upland plot—Besides the fact that the use of an upland or dry plot results in more severe blast development there are also other advantages in using a dry nursery. These include a more uniform stand of seedlings, greater ease in handling the dry seeds, and greater convenience in working. In Thailand, most rice fields are flooded during the rainy season. Experimental plots therefore had to be raised about one foot above the prevailing water level. The plots should be about 2 meters wide and of any convenient length (see Methods of Planting, below).

2) Soil fertility—Experiments in Thailand have shown that blast lesions increase with increasing applications to the soil of ammonium sulfate. It was decided that ammonium sulfate should be added to the experimental plots at the rate of 600 kgs. per hectare, one half of which should be applied just before sowing and the other half as a top dressing 15 days after seeding. In addition, superphosphate should be added at the rate of 300 kgs. per hectare

before planting to encourage vigorous growth. These rates of application of fertilizers were such as to cause a complete kill of susceptible varieties.

3) Time of testing—It was found that the best time to test for blast resistance in Thailand occurred between June and February as an adequate water supply was assured for that time of year. The most favorable time occuring during the tillering stage of the normal rice crop as studies have shown that the air-bourne spores of blast are most abundant during this period.

4) Methods of planting:

(a) Testing row—Ordinarily a 50 cm. row is sufficient. If the seedlings are to be used for other purposes the length of the row can, of course, be increased to obtain the necessary number of seedlings.

(b) Rate of seeding—Five grams of seed are used for the 50 cm. row in order to have a dense enough stand to retain a high humidity in the micro-climate.

(c) Spacing—The rows should be 10 cm. apart. This close spacing helps in retaining high humidity.

(d) Check rows—In critical tests a susceptible variety row should be planted between every two test rows. These check rows serve as a source of inoculum. Resistant varieties should be planted every 20 rows, i.e. every 2 meters.

(e) Border rows—In view of the differences in the micro-climate in different parts of the seedbed, border rows are often necessary to ensure high humidity and uniform micro-climatic conditions in the test rows. At Bangkhen, three rows on the windward side, two rows on the leeward side and three or four rows at each end of the plot were normally sufficient. The border rows at both sides are planted at right angles to the test rows with the same spacing and rate of seeding. A susceptible variety should be used for the border rows.

5) Mulching and watering—Mulching is very helpful in preventing or reducing the damage caused by heavy rain showers, birds etc. and also helps to retain more uniform soil moisture in the early stages. Rice straw is most convenient for mulching but the tops have to be chopped off and discarded in order to eliminate any seed that might still be attached. The plot must be kept moist and watering is necessary. On dry days watering two or three or even more times daily is needed.

6) Replication—Replications are desirable for more reliable results. However, in the case of preliminary screening when a large number of varieties are often involved, a single row will give sufficient information as the susceptible and resistant checks are nearby for comparison. The reaction of the more resistant varieties may be confirmed by additional tests and the work-load may thus be reduced.

In addition to screening uniform varieties for resistance, this method is useful for selecting individual resistant plants from crosses or mixed lots of seed. In 1960, the bulked progenies of crosses between resistant and susceptible varieties at F_5 were tested using the method described above. The disease reaction of the progeny varied from very resistant to very susceptible in each row. The seedlings of resistant groups (explained below) were selected and transplanted, at a single seedling per hill. Five hundred to one thousand plants were selected from progeny of each cross at the end of the season. In 1961, the seeds of the selected plants, now considered as separate pedigree lines,

were tested again to confirm their resistance. Very few lines in the confirmation test of 1961 showed susceptibility. This indicates that very few susceptible seedlings had escaped from the disease in the test of 1960.

In scoring disease reaction, the type of lesion, the number of lesions and the color of lesions have often been considered as criteria. Considering the practical importance of the three criteria and avoiding complicated systems of scoring, 8 groups of disease reaction are recognized in classifying the degree of resistance in Thailand. The 8 groups are described below:

Group 1.—Only small brown specks of pin-head size are produced on leaves, few or many, sometimes unrecognizable, with no necrotic spots.

Group 2.—Slightly larger brown specks, about ½ mm. in diameter, with no necrotic spots.

Group 3.—Small, roundish, necrotic, grey spots about 1-2 mm. in diameter, surrounded by a brown margin which is roundish or tends to be elliptical; the lesions may be many but leaves are not killed.

Group 4.—Typical blast lesions, elliptical, 1-2 cm. long with large necrotic, grey, centers and brown or reddish brown margins, usually relatively few on a leaf, less than 5% of leaf area is damaged.

Group 5.—Many large blast lesions as in Group 4 or larger, the upper portion of one or two leaves of a seedling of 4 or 5 leaves may be killed by coalescing of lesions, the total area killed however does not exceed 25 %.

Group 6.—Lesions as in Group 5 but more numerous, so that one or two leaf blades may be completely withered and the total area killed may reach 50%; the color of the margins of lesions often show less brown color but tend to yellowish or greyish brown.

Group 7.—Large, quickly expanding lesions, the margins mostly grey with a brown tinge; most of the expanded leaves are killed but young ones remain, typically 75-80% of the leaf area is killed.

Group 8.—Large, quickly expanding lesions, entirely grey, leaves are completely killed.

To give a general idea of resistance, groups 1-3 may be considered resistant, 4-8 susceptible; or 1-3 resistant, 4-5 intermediate, 6-8 susceptible; or 1-2 highly resistant, 3-4 resistant, 5-6 susceptible and 7-8 very susceptible.

A suitable time for taking readings in these tests in Thailand is about 30 days after sowing when varieties will exhibit clearly their different degrees of resistance.

Varietal Resistance to Blast

About 1,700 varieties and strains of rice have been tested for blast resistance in the seedling stage by natural infection in upland conditions as described above. About 1,100 of the above varieties and strains were those under "Variety Trial" experiments in three major rice producing regions of Thailand, the North, the North-East, and the Central region. In addition, some floating rice varieties were used. Varieties from the North are mostly glutinous, from the North-East, glutinous and non-glutinous in about equal numbers and from the Central region, all non-glutinous, typical or representative of the *indica* type of rice in Thailand. The following table shows the number of varieties in different groups of resistance from the different regions.

Number of resistant, intermediate and susceptible rice varieties from different regions of Thailand

Region or type	Resistant (groups 1-3)	Intermediate (groups 4-5)	Susceptible (groups 6-8)	Total
North	101	89	83	273
North-East	84	69	58	211
Floating	7	246	9	262
Central	48	162	160	370
	240	566	310	1,116

These results indicate that the percentage of resistant varieties is about equal in the North and North-East and that a greater percentage of the varieties are susceptible in the central region. The floating varieties are mostly in the intermediate group.

Resistance in the progeny of various crosses

1) Resistance in F_5 and F_6 populations

Large numbers of crosses have been made since 1955 in the hybridization program. Each cross has been grown as a bulked population. In 1960, some of the progenies reached F_5 and as the resistance of the parental stocks to blast was found out after testing, they were selected for breeding resistant varieties. Progeny of each cross was tested for seedling blast resistance by the upland method and resistant individuals were selected. Samples of seeds of these progenies were tested separately and the segregating populations in various groups of resistance and susceptibility were counted. The following results were obtained:

Reaction of Seedlings to the Progenies of Various Crosses to Blast

Cross	Number of seedlings in different groups of resistance								
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Total No. seedlings
Nahng Mon S-4 (resistant)	98		52	13			1		164
	18			1			1		20*
Khao Tah Haeng 17 (susceptible)								2,000	2,000
NM S-4×Leuang Yai 34 (resistant), F_5	55	73	67						195
NM S-4×Puang Nahk 16 (susceptible), F_5	62	65	42	10	10	2	4	7	202
NM S-4×Leuang Awn 29 (susceptible), F_5	29	47	23	31	32	15	8	4	189
NM S-4×Khao Tah Haeng 17, F_5	8	59	29	15	16	19	35	21	202
	1	25	29	36	27	56	40	24	237*
NM S-4×Leaung Rah Haeng 8 (moderately resist.), F_5	28	54	43	25	19	6	2	1	178
KTH×NM S-4, F_4	1	55	17	18	11	2	16	30	153

* Artificial inoculation in wooden flats.
Note: NM = Nahng Mon
KTH = Khao Tah Haeng

The resistant seedlings (groups 1, 2, 3) selected in F_5 did not segregate in F_6, no susceptible individuals being found in a sample test of about 450 individuals. In the cross of Nahng Mon S-4×Khao Tah Haeng 17, the 1,000 resistant plants selected in F_5 showed 3 very susceptible and 30 slightly more susceptible plants in F_6 when a confirmation test was made in 1961. The presence of these susceptible plants may be due to some susceptible plants having been over-looked when the individual seedlings were inspected in the F_5 test. In the sample test, the very susceptible groups (groups 7, 8) in F_5 remained very susceptible in F_6. Individuals from intermediate groups segregated into more resistant and more susceptible groups.

2) Resistance in the F_2 population

Twenty-three crosses were made in the spring of 1960 and by dark-room forcing the F_2 population (150-300 individuals) of each cross was tested in the field for blast resistance in the fall. Varieties used in these crosses consisted of resistant (R), moderately resistant (M), and susceptible (S) groups. Combinations were made between R × R, R × M, R × S, M × M, M × S and S × S. The results of the blast resistance test showed that in general, the F_2 progeny of R × R were all resistant (groups 1, 2, 3); of R × M, mostly in between R and M; of R × S, varying from resistant to susceptible and mostly in intermediate groups; of M × M, also varying from resistant to susceptible, beyond the range of the parental varieties; of M × S, mostly between the parental ranges; and of S × S, all susceptible. The only exception seemed to occur in the cross between Puang Nahk 26 (susceptible) × Nahng Mon S-4 (resistant), when the F_2 progeny were all found to be in resistant groups.

An exact genetical interpretation of the above results is not intended at the present moment as some of the basic problems have to be clarified, such as the genetic purity or uniformity as regards blast resistance of the parental varieties, the extent of variation caused by environmental conditions etc. The general impression, however, is that the resistance of rice varieties to blast, as far as the above materials are concerned, is governed by several pairs of genes.

Leaf blast and "neck-rot" resistance

Neck-rot is another important phase of blast disease in Thailand. Whether varieties or progenies resistant to blast in the seedling stage will be also resistant to neck-rot is an important question and some workers have reported that plants resistant to leaf blast may not be resistant to neck-rot. In the fall of 1960, because of late rains, the climatic conditions were very favorable for the development of neck-rot. Three sets of data were recorded which indicated that resistance in the seedling stage is closely correlated with resistance in the heading stage, or in other words, when the seedling is resistant to leaf blast the mature plant will also be resistant to neck-rot. The three sets of data may be presented briefly as follows:

1) At Bangkhen Rice Station, the resistant progeny (group 1, 2 and 3 of disease reaction in the seedling stage) of the cross Nahng Mon S-4×Khao Tah Haeng 17 at F_5 and the susceptible variety Khao Tah Haeng 17 were planted in adjacent fields. The percentages of neck-rot were counted as follows:

Resistant progeny of Nahng Mon S-4×Khao Tah Haeng 17, F_5

Resistant group 1	0/1,235*	tillers	0%	neck-rot
" " 2	3/1,387	"	0.22%	"
" " 3	9/1,245	"	0.72%	"

* Number of infected tillers/total number of tillers

Khao Tah Haeng 17

Sample 1	113/483	tillers	23.4%	neck-rot
„ 2	71/254	„	28.0%	„

2) The F_6 progeny of the cross Nahng Mon S-4×Khao Tah Haeng 17 in various groups of resistance were planted in a small field. Among them were planted three small plots of Khao Tah Haeng 17, 3 rows in each plot to serve as checks. The percentages of neck-rot were as follows:

Resistant progeny of Nahng Mon S-4×Khao Tah Haeng 17, F_6

Group 1	0/300	tillers	0%	neck-rot
„ 2	0/300	„	0%	„
„ 3	0/300	„	0%	„

Khao Tah Haeng 17

Check 1	51/200	tillers	25.5%	neck-rot
„ 2	72/200	„	36.0%	„
„ 3	90/280	„	32.1%	„

3) During the test for varietal resistance to blast, seedlings of 115 resistant varieties were saved after the test and were transplanted in small plots of 3 rows each 5 meters long. Five plots of susceptible Khao Tah Haeng 17 were inserted to serve as checks throughout the field. Three weeks after heading counts of the percentage of neck-rot were made. While the 5 checks of Khao Tah Haeng 17 had 18.85%, 21%, 17%, 17.6% and 24.4% of neck-rot, only two of the resistant varieties had any neck-rot. Of these, "20 Bkg" had 0.7% (the original disease reaction in the seedling stage had been group 1, 2 with very few seedlings in group 2) infection. Another variety planted in this test was "Bow Luang 2" which was in group 3, 4 as regards disease reaction in the seedling stage and had 2.7% neck-rot.

In considering neck-rot, it should be pointed out that as in leaf infection there are differences in the degree of damage caused. When the lesions are small, the grains are still able to fill more or less normally as in the case of most of the resistant plants. When the lesions expand quickly, they soon girdle the peduncles and only empty white ears are produced as in the case of susceptible plants. The time of infection also accounts for differences. Thus with late infection of a susceptible plant the grains may be able to fill partly. The percentages of neck-rot mentioned above refer to white ears or to very lightly filled panicles only. Small lesions were found on the resistant varieties but little damage seemed to result.

The above data seem to show that resistance in the seedling stage indicates resistance to neck-rot. The reaction in the two stages may be different, however, if different races of the fungus are present in the later stage.

MAXIMUM TOLERANCE OF RICE SEEDLINGS TO DIFFERENT SALT CONCENTRATIONS OF IRRIGATION WATER[1]

C.L. Pan and Habib Ben Jemia[2]

Introduction

In Tunisia, attempts are being made to grow rice using the water of the Medjerda River which contains salt with concentrations varying from 1.5 to 6.0 millimhos, a measurement of the electrical conductivity and each millimho indicates roughly a salt concentration of 0.66 gram per litre of water.

A trial in pots was made during 1960 and 1961 to study the tolerance of rice to various salt concentrations of the irrigation water during the seedling stage.

Methods

Rice was planted in pots of about 25 cm. in diameter and 40 cm. in height. At about 5 cm. from the bottom of each pot was made a small opening into which was inserted a plastic tube for drainage. A layer of fine gravel was laid in the bottom of each pot above which soil taken from the Medjerda Valley was placed. After planting, the pots were irrigated once every 4 days with water of various salt concentrations which were artificially constituted by adding sodium chloride, calcium sulphate and magnesium sulphate to rain water in a proportion similar to the water of the Medjerda River. Before each irrigation, the water remaining from the previous irrigation was drained.

Five weeks after planting, the seedlings were pulled out and counted. The number of tillers and measurement of the height of seedlings and length of roots were recorded. After recording, each pot was replanted with the seedlings from the same pot in 4 hills of 3 seediings in order to study the mature-plant tolerance to salinity. This paper, however, reports only the data obtained from the measurement of the seedling characters.

Experimental Results

1) Results obtained In 1960

Five grams of the seeds of the variety Balilla were sown in each of 40 pots on the 11th of May. The pots were irrigated with 5 kinds of water, namely, (1) rainwater which practically contains no salt, (2) water from the Medjerda River which had an electrical conductivity of about 3 millimhos during most time of the season, and (3) the remaining 3 artificially salinized waters which had different concentrations of salt, namely 3 millimhos, 6 millimhos and 9 millimhos. The pots were irrigated at two different depths of 3 and 6 cm. Thus, this trial consisted of 10 treatments in a factorial combination of 5×2. Each of the 10 treatments was replicated 4 times, thus giving a total of 40 pots.

On the 15th of June, 35 days after sowing, the measurement of 4 seedling characters were made.

As the amount of seeds sown to each pot was the same, the number of seedlings obtained on the 15th of June can thus represent the rate of seedling survival in each pot.

The data obtained are presented in Table 1.

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1 Contribution from the Service Botanique & Agronomique of the Government of Tunisia.

2 FAO Rice Expert in Tunisia, and Aide Technique, Service Botanique & Agronomique. The writers wish to express their thanks to Mr. Seguela, the Director of the Service Botanique & Agronomique, for his approval to conduct this trial and to Mrs. L. Holderback, Ingenieur au Laboratoire de Pedologie, for her assistance in preparing the artificially salinized waters. The writers also wish to thank M. Essafi Abdelhamid, Acting Director, Service Botanique & Agronomique for his approval to publish this article.

TABLE 1

Average measurement of the 4 seedling characters

Treatments		Percentage of seedlings survived	Number of tillers per seedling	Height of the seedlings in cm.	Length of the root in cm.
Rain water	3cm	51.2	3.3	21.7	17.6
	6cm	53.5	3.8	20.6	16.0
Medjerda water	3cm	37.5	2.8	17.8	14.6
	6cm	48.5	3.6	17.1	14.7
3 Millimhos	3cm	12.5	1.0	14.8	4.3
	6cm	37.0	2.5	40.1	8.4
6 Millimhos	3cm	0.5	0.2	14.0	0.5
	6cm	11.8	1.0	13.2	3.3
9 Millimhos	3cm	0.0	0.0	0.0	0.0
	6cm	3.2	0.5	11.5	2.3

At irrigation depth of 3 cm. all plants died when watered with 6 or 9 millimhos, whereas at 6 cm. some seedlings survived even when irrigated with 9 milliomhos. But it can be seen from the data that all the characters measured have shown a sharp decline at 6 and 9 millimhos. For instance, the number of tillers at the irrigation depth of 3 cm. has reduced from 1.0 when irrigated with 3 millimhos to only 0.2 when irrigated with 6 millimhos. It seems that the limit of tolerance lies between 3 and 6 millimhos. This was later proved by the fact that all the transplanted seedlings in pots irrigated with water of 6 and 9 millimhos died in a few days after transplanting, whereas those in pots with 3 millimhos reached maturity, although a few days later than those irrigated with rain water.

2) Results obtained in 1961

A new trial was conducted in 1961 with the object of finding the more exact limit of tolerance beyond 3 millimhos. Three varieties of rice, namely, Balilla, France 1 and Stirpe 136, were planted in pots irrigated at the depth of 3 and 6 cm. with rain water, and saline waters of 3 millimhos, 4 millimhos and 5 millimhos. With two replications for each treatment this trial thus consisted of 48 pots in all.

One hundred seeds of each of the 3 varieties were planted to each pot on 12 May and measurement of the various seedling characters was made on the 17th of June.

Analysis of variance was made for the data of the 4 characters with a total of 23 degrees of freedom for the treatments, which were further divided into 3 main effects and first and second order interaction. Since the interactions were all found insignificant, they were therefore pooled with the degrees of freedom for the error.

The results are given below:

TABLE 2

Analysis of variance for the 4 seedling characters

Variation due to	Degrees of freedom	Mean squares %of seedlings survived	No. of tillers	Height of plant	Length of root
Variety	2	2,092.69**	1.27**	496.46**	50.20**
Depth of irrigation	1	325.53	0.66	35.37	1.20
Kind of water	3	3,288.13**	8.17**	1,413.20**	301.52**
Error	41	174.93	0.28	42.94	8.12

** Significant at 1% level.

The data given in the above table have shown that only mean squares for the depths of irrigation failed to reach the level of significance indicating that the growth of rice had shown no significant difference whether it was irrigated with 3 cm. or with 6 cm. depth of water. This does not agree with the results obtained in 1960 when rice at 6 cm. depth of irrigation was found growing definitely better than that at 3 cm. depth.

The mean squares of all the 4 seedling characters for both varieties and for the qualities of the water were found to be highly significant. Their means together with their values of D are given below.

TABLE 3

The mean measurement of the 4 seedling characters for varieties and for the quality of water and their value of D

	Percentage of seedlings survived	No. of tillers per seedling	Height of plant in cm.	Lenght of root in cm.
Rain water				
Balilla	41.8	2.6	25.4	14.6
France 1	49.8	2.4	36.1	14.0
Stirpe 136	19.2	1.8	24.3	9.0
3 millimhos				
Balilla	28.2	1.5	19.7	7.0
France	59.8	1.7	32.0	10.5
Stirpe 136	27.8	1.5	23.0	7.4
4 millimhos				
Balilla	6.25	0.8	10.4	3.0
France	12.25	0.8	12.8	2.9
Stirpe 136	6.50	0.5	6.0	1.4
5 millimhos				
Balilla	8.00	0.5	6.0	3.0
France 1	21.8	1.0	14.5	4.6
D	32.40	1.3	16.1	7.0

D as given at the bottom of the table is used to test the significance of differences as suggested by Snedecor ("Statistical Methods" fifth edition, 1957, pp. 251-253). It is the product of Sx and a factor called q which can be found in a table on page 252 of Snedecor's book.

Balilla had 41.8% seedling survival when irrigated with rain water as compared with 8.0% when irrigated with water of 5 millimhos, the difference of 33.8 being greater than the D value of 32.4, and the difference is therefore considered to be significant.

The data from table 3 have shown that all the seedlings of Stirpe 136 died before June 17 when irrigated with water of 5 millimhos. This means that this variety has its limit of tolerance at 4 millimhos.

France 1, however, has shown a much greater tolerance as it still had 21.8% of seedling survival at 5 millimhos, which did not differ significantly from percentage of survival when irrigated with rain water.

The limit of tolerance of the variety Balilla seemed to lie also at more than 5 millimhos although the percentage of seedlings surviving at both 4 and 5 millimhos was significantly lower than when irrigated with rain water.

It is to be noticed that the effect of salinity on tillering, height of plant and the length of root appeared to be similar to the effect on seedling survival.

Conclusion

In 1960 the trial consisted of only one variety, Balilla; and the data have shown that its limit of tolerance seemed to lie between 3 and 6 millimhos.

In 1961, 3 varieties namely, Balilla, France 1, and Stirpe 136, were tested; and it was found that the tolerance of rice to salinity differed among varieties. Stirpe 136 seemed to have its maximum tolerance at 4 millimhos as all plants died at 5 millimhos. Balilla, however, still had several seedlings alive at 5 millimhos indicating that its limit of tolerance lay beyond this limit. France 1 was even more tolerant as there were many plants alive at 5 millimhos, the number of surviving plants at this concentration even being not significantly less than when irrigated with rain water.

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